NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 18-90

EVALUATION OF MAKO 5407 BAD DIESEL HIGH PRESSURE BREATHING AIR COMPRESSOR

GEORGE D. SULLIVAN

SEPTEMBER 1990

NAVY EXPERIMENTAL DIVING UNIT

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

IN REPLY REFER TO:

NAVSEA Task 89-11

NAVY EXPERIMENTAL DIVING UNIT

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

In response to reference (1) and as outlined in reference (2) the Navy Experimantal Diving Unit (NEDU) tested the MAKO 5407 diesel powered high pressure, breathing air compressor from 1 June 90 to 15 June 90. The purpose of this test was to determine if the equipment was suitable for use by the United States Navy (USN) diving community and if so, added to the Approved for Navy Use (ANU) Procurement List.The MAKO 5407 met manufacturers specifications for quanity of air produced with a quality which met or exceeded purity standards in reference (3).The design and engineering was determined to be adequate.With the inclusion of the recommendations in section V the MAKO 5407 compressor is considered suitable for USN requirements for compressors of this size and type.

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CONTENTS

I. INTRODUCTION

Per reference (1) and as detailed in APPENDIX A, the MAKO Diesel powered 5407 high pressure breathing air compressor was tested by NEDU. The test was to determine if the compressor would provide suitable breathing air and a service life satisfying the U.S. Navy requirements for divers air supply compressors. Other material variations were also evaluated and are listed as considerations in Section V.

Highly portable diver's air compressors are designed to provide high pressure air with relatively low volume outputs. Divers require low pressure air with high volume. The average divers high pressure air compressor is connected to large volume high pressure air storage flasks to meet this need. In normal operation the high pressure air is reduced to a lower pressure to act as a breathing media for divers. As this is accomplished, the pressure gradually reduces in the storage flasks. The compressors tend to run on a continuous basis as the diving day continues since the demand is usually greater than the supply. At the end of the diving day or when air requirements are reduced, the compressors will exceed the demand and fill the air flasks.

There are various methods of testing compressor capacities. For the purposes of this test, NEDU chose a method consisting of charging the storage flasks from 0 to 2500 psig daily then opening the vent and maintaining 1500 + psig for continuous run. This method more closely simulated the use a compressor would experience in the field. Additionally during the continuous run, random charge rates were taken from 1500 to 2500 psig. The compressor was operated a total of 50 test hours. Testing included subjective evaluation of the system operation but did not include detailed mechanical review of the individual components of the system.

II. EQUIPMENT DESCRIPTION

The MAKO 5407 high pressure, breathing air, compressor (Figure 1) is a four stage, four cylinder, "V" configuration, cooled by a large pulley driven variable pitch fan. Air for compression enters via the intake filter and passes to the first stage cylinder where it is compressed to approximately 64 psig. Passing through a heat exchanger to the second stage it is then compressed to 280 psig. On exit from the second stage it flows through a cooling system positioned in the fan airstream, and then into a separator for condensate removal. On entering the third stage the air is further compressed to 1210 psig, before passing through the third stage cooling coil and condensate removal separator. Final compression pressure of 5075 psig takes place in the fourth stage, then passes through a finned cooling system. Final delivery is made at approximately 18 degrees Fahrenheit above ambient.

All stages are lubricated by means of the force-fed lubrication system. The compressor requires approximately 2.5 quarts (US) of lubricating oil. The manufacture recommends that either MAKO compressor oil (mineral) or MAKO synthetic compressor oil be used. These oils are not stocked in the Federal Supply System. As an alternative, MAKO suggests use of Anderol 500 synthetic oil as a substitute after 50 hours of run time. While Anderol is a Federal stock item 2190 TEP is currently the only lubricant authorized for breathing compressor use by the U.S. Navy.

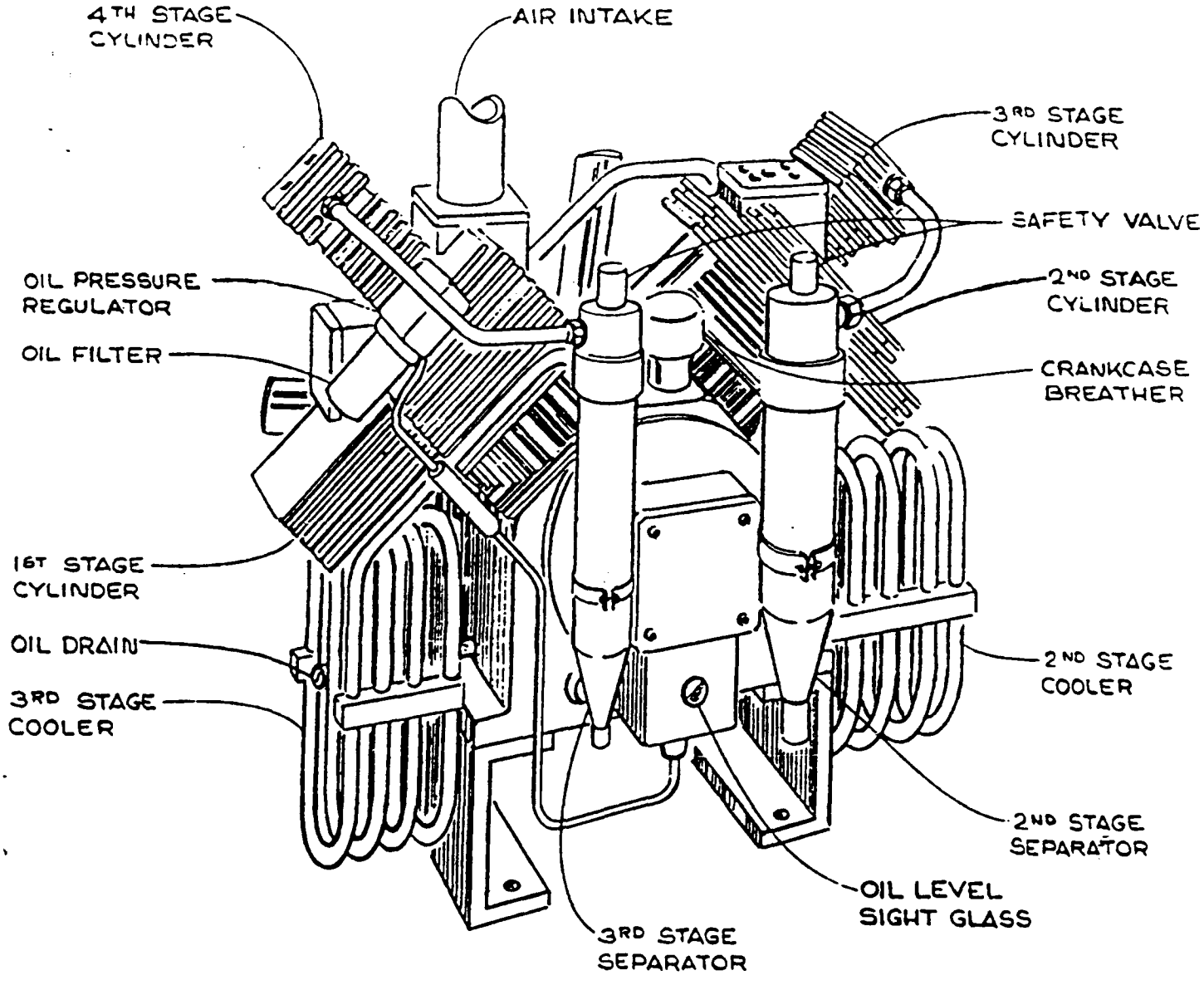
4TH STAGE CYLINDER
AIR INTAKE
3RD STAGE CYLINDER
SAFETY VALVE
OIL PRESSURE REGULATOR
2ND STAGE CYLINDER
OIL FILTER
CRANKCASE BREATHER
1ST STAGE CYLINDER
OIL DRAIN
2ND STAGE COOLER
3RD STAGE COOLER
2ND STAGE SEPARATOR
OIL LEVEL SIGHT GLASS
3RD STAGE SEPARATOR

Figure 1

As directed by NAVSEA the compressor oil was changed at 13 hours to 2190 TEP and used through out the remaining hours of the test. Seven hours after the oil change the oil pressure dropped to 990 psig. It was adjusted to 1025 psig using the adjustment screw located on top of the oil regulator body. No further problems with oil pressure or temperature occurred.

The prime mover is a LISTER PETTER T series, two cylinder, direct injection, flywheel fan air cooled diesel engine. Rotational torque is transferred to the compressor by a single banded belt.

The filtration available system is a multi chambered unit constructed of aluminum alloy, designed for 5000 psig working pressure. The first chamber is a mechanical separator to remove oil and water. Subsequent chambers utilize replaceable cartridges to remove water vapor, hydrocarbons, noxious gases, taste and order. Carbon Monoxide is also eliminated by catalytic oxidation. The final chamber includes a visual moisture and carbon monoxide monitor. For this test the MK 2 C system using the MAKO 1803 filter cartridge was used.

A pressure maintaining/non-return valve is provided down stream from the filter system to ensure that pressure build up occurs in the filters during start up and initial compressor air delivery. This provides for constant, optimum filtering, moisture separation and prevents compressed air from returning from the charged air storage tanks to the compressor during unit shut down. All four stages of the compressor are protected by safety relief valves.

III. TEST PROCEDURE

The compressor and all ancillary equipment were set up in accordance with the manufacturer's instructions. A Cole Parmer model 8502-14 temperature monitor and Yellow Springs Instruments 700 series thermistor probes were attached to measure compressor discharge and ambient temperatures. A safety line was installed on the charging whip. The unit was placed in an exterior work area, open to ambient temperature but protected by an awning from direct weather. APPENDIX A contains the complete test plan and the pass/fail criteria used during the evaluation. APPENDIX B is the test log and contains the recorded data.

A. ENDURANCE TEST

The compressor was operated daily to charge four 2250 cubic inch (floodable volume) cylinders. The four cylinders were interconnected to simulate one large air flask. After achieving a charge of 2500 psig on the flasks, the vent was opened with the compressor supplying 1500 + psig. Since the compressor filter flask holds 1500 psig, the charge rate was verified by charging from 1500 to 2500 psig. A total of 50 hours of operation was logged. The following parameters were recorded:

(1) Date
(2) Time
(3) Total meter hours
(4) Total test hours
(5) Oil level
(6) Oil pressure
(7) All four stage pressures

differentials between ambient and compressor discharge temperatures were 5 to 8 degrees Fahrenheit. The maximum recorded differential temperature was taken immediately after startup. It is not considered to be a true reading due to the chilling effect caused by the expansion of the compressed air dumping from a relatively high pressure (1500 psig) in the filter housing to a lower pressure in the empty storage flasks.

C. OIL CONSUMPTION

The compressor consumed a total of 12 ounces of oil after the oil change conducted 13 hours into the evaluation. Average consumption was 0.32 ounces per hour and is considered insignificant.

D. AIR SAMPLING

The results of the air samples are shown in APPENDIX C. All samples were within limits established by reference (2).

E. MAINTENANCE

Maintenance performed consisted of the following:

At 6 hours 30 minutes the green high air pressure indicator came on with a discharge pressure of 1804 psig. The unit did not shut down. All other gauges and indicators remained normal. Discussion with MAKO representative determined the switch to be faulty. At 13 hours the original oil was changed. At 37 hours the filter was changed. This included a thorough cleaning in accordance with the manufacturers instructions. The oil sump level and the CO2/moisture indicators were checked prior to start-up each day. At 28 hours 18 minutes the total hour meter stopped. The test was continued using a standard 12 hour clock. The MAKO 5407 compressor unit was easily maintained. No significant problems were encountered.

V. RECOMMENDATIONS

The Vendor and NAVSEA should be contacted prior to purchase to ensure the unit meets the users needs.

The following considerations should be addressed by the user when purchasing this compressor (these are only considerations and not requirements):

A. Cadmium coated fittings be replaced with a suitable substitute.

Justification: Reference (3) states that cadmium coated fittings cannot be used in systems that exceed 400 degrees Fahrenheit or if the cadmium could come in contact with petroleum products. The only HP compressor lubricant currently authorized by the NAVY is 2190 TEP, resulting in possible petroleum product contact.

B. Provide a level indicator for the fuel tank.

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

IN REPLY REFER TO:

NAVSEA TASK 89-11

NAVY EXPERIMENTAL DIVING UNIT

STANDARD TEST PLAN

MAKO MODEL 5407-BAD DIESEL DRIVE HIGH PRESSURE AIR COMPRESSOR

TEST PLAN NUMBER 90-15

APRIL 1990

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Original to Technical Library

RECORD OF CHANGES

Except as provided for herein, changes will be made only on the authority of the Commanding Officer, NEDU. A dark vertical line in the left-hand margin indicates the coverage of change.

CHANGE NO.	AUTHORITY	INSERTION	SECTION	INITIAL

TABLE OF CONTENTS

References:

(a) NAVSEA Task 89-11 Evaluation of Commercially Available Divers Air Compressors.
(b) NAVAL EXPERIMENTAL DIVING UNIT TEST EVALUATION NUMBER 80-37
(c) NAVAL COASTAL SYSTEM CENTER Field Test Procedure SP80-13-0S6 for Testing Diving Air Compressors
(d) Mako Publication Number 54067 M 89 A, for Model 5407-BAD Diesel Drive High Pressure Air Compressor
(e) NAVSEA 0994 - LP001-9010, US Navy Diving Manual Volume 1 paragraph 5.3.2 Air Purity Standards

1. Introduction. This test plan provides a series of procedures for standardized evaluation of commercially available divers high pressure air compressors. The compressors will be evaluated and data compiled during these test to determine their suitability and reliability; and possible approval for Navy use (ANU). This particular document is to evaluate the MAKO Model 5407 BAD Diesel Drive Compressor.

NAVSEA 00C Memo Task 89-11 directed NEDU to survey the commercial domestic market to determine if currently available high and low pressure compressors are applicable for fleet use. If applicable procure compressor systems as required for evaluation. Make recommendations for inclusion on Approved for Navy Use (ANU) listings.

2. Test Parameters. Evaluation of the compressor will be conducted as follows:

a. Receipt of compressor at NEDU, Panama City.

b. Conduct inspection of compressor using manufacturer's instruction manuals as references to ensure all parts and material are received and on hand.

c. Using the manufacturer's technical manual for the specific air compressor and its components, inspect for and determine if the following items exist and/or comply, and record results and comments in Annex A:

(1) All instruments and controls are clearly and permanently marked according to their functions.

(2) All controls, gauges and indicators necessary for operation of the compressor are visible and convenient to the operator.

(3) Safety devices are provided and audible and/or visual warning functions as specified.

(4) Liquid level indicators accurately display liquid level.

(5) All removable components can be removed and properly re-installed in working conditions using the manufacturer's operating manual i.e. filters.

(6) All drain, trap and safety valve discharge ports will function without splashing, are conveniently located, and are away from operating personnel.

d. Have all instrumentation provided by manufacturer compared and or calibrated, and accompanied with certification.

e. Operate the compressor for one (1) hour under a no load condition.

f. Take air samples following no-load test run, and have gas analysis conducted.

g. Conduct Testing in accordance with the procedures set forth in section 4. Total compressor running time will be 50 hours.

3. Preliminary Arrangements

a. Arrange for air analysis to be conducted as required.

b. Prior to the actual test procedure the air compressor system shall be operated then shut down when the system is at maximum pressure and the following steps accomplished.

(1) Hold pressure.

(2) Allow the system to cool to ambient temperature.

(3) After temperature has stabilized, record the storage flask pressure.

(4) After an eight hour period, record pressure again.

(5) Leak rate shall be zero.

4. Test Procedure. The following test procedures will be conducted as specified, and the results entered in the log sheets, Annex A.

a. Take air samples at hours 1, 25, 50, and anytime air quality is questioned.

b. Log the following measurements on the log sheet Annex A.

(1) Date

(2) Time

(3) Compressor meter hour (if applicable)

(4) Total hours running time on compressor (this test)

(5) compressor oil level

(6) Compressor oil pressure

(7) 1st Stage pressure

(8) 2nd Stage pressure

(9) 3rd Stage pressure

(10) 4th Stage pressure

(11) Discharge air temperature

(12) Ambient air temperature

(13) Flask size and pressure

(14) Remarks

c. The compressor air system shall be set to run continuously by adjusting controls and bleed off rate.

d. Compute volume output of the compressor by charging a known volume storage flask to 2500 psig. Log total charging time and calculate charging rate.

e. Oil consumption shall be measured and recorded during testing, with measurements and additions entered in the log.

f. Perform maintenance as required by the manufacturer's instruction manuals.

5. Post Test Arrangements. Make all necessary arrangements as previously determined to return compressors system and test fixtures to proper locations.

6. Personnel Requirements. NEDU Hyperbaric and/or Test and Evaluation Department personnel (1 each).

7. Safety Rules and Emergency Procedures. Safety rules and precautions as outlined in the specific manufacturer's instruction manuals.

8. Logistical Support. A air analysis.

9. Funding Source. NAVSEA OOC Task No. 89-11.

10. Report Production. Test report and camera ready copy to be written and prepared by the Test Director and submitted for approval to the Commanding Officer via the Task Leader. Estimated and publication date is six (6) weeks following completion of testing. Test Directors will be the point of contact for NEDU concerning this test and will be appointed by the Task Leader.

11. Comments and Additional Information. The NEDU Task Leader is responsible for the following:

a. Control and Safety of Systems. All control systems, safety systems and valves shall be activated by making the necessary temporary alterations to the compressor controls and operations whenever such alterations will not result in a risk of damage to the compressor unit. Where a risk is present, the test may be conducted with control systems completely removed from the compressor unit by subjecting control system sensors to other sources of temperature and pressure; for example, the oil safety switches and sensors, automatic condensate blow down valves overpressure switches and sensor, high temperature switches and sensors, and other devices designed to operate or protect the system and attending personnel.

b. Termination Criteria. The following is F lure Criteria for the suitability for the specific compressor system fc_ ANU:

(1) Failure of any component which cannot be corrected in accordance with the recommended schedule of maintenance.

(2) Failure of the diving air system to operate as specified by the manufacturer's instruction manuals.

(3) Failure of the valves to operate as specified.

(4) Failure of the pressure relief valves to operate as specified.

(5) A decrease in capacity of the compressor during this performance evaluation.

(6) A discharge air temperature from any cylinder in excess of manufacturer's specifications or recommendations.

(7) Failure of the air samples to pass breathing air specifications as listed in reference (e).

DATE	TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEVEL	OIL PRESS.	STAGE PRESS 1	2	3	4	DISC AIR TEMP.	AMBIENT AIR TEMP.	FLASK SIZE	FLASK PRESS.	REMARKS

ANNEX A - 1

MAKO DIVERS AIR COMPRESSOR
MODEL 5407 BAD

1990 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
5 31	1300											2500	Charge and hold
6 01	0700											2390	Leak test/air samp
6 01	0800	2.0	0	3/4	1010	38	230	860	1600	71.4	76.1	1950	Ck oil/top up fuel
6 01	0900	3.0	1	3/4	1010	60	245	900	2000	86.9	81.3	1990	Vent opn Adj oil pr
6 01	1000	4.0	2	3/4	1010	60	245	880	1950	88.1	82.6	1900	
6 01	1100	5.0	3	3/4	1010	60	245	910	2200	94.6	89.1	2150	2.5 gal fuel
6 01	1135	charge rate 22 min 45 sec 1500 to 2500 psig											opened vent
6 01	1200	6.0	4	3/4	1010	65	250	950	2400	95.7	89.9	2400	Vent open
6 01	1300	7.0	5	1/2	1010	60	245	890	2000	94.9	88.5	1980	Vent Open
6 01	1400	8.0	6	1/2	1010	60	245	900	2050	94.4	89.1	1980	Vent Open
6 01	1430	8.5	6.5	1/2	1010	60	245	875	1900	92.3	88.2	1840	Vent Open
6 04	0700	8.5	6.5	3/4	1010	60	230	800	1100	72.4	85.3	200	2.5 gal fuel
6 04	0800	9.5	7.5	3/4	1010	55	245	880	2000	92.9	84.2	2010	Opened Vent
6 04	0900	10.5	8.5	1/2	1010	60	245	850	2000	92.1	86.3	2100	Vent Open

MAKO DIVERS AIR COMPRESSOR
MODEL 5407 BAD

1989 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
6 04	1000	11.5	9.5	1/2	1010	60	245	850	2100	89.3	81.9	2100	Vnt Opn/2.5 gl fuel
6 04	1100	12.5	10.5	1/2	1010	60	245	900	2100	91.1	83.6	2090	Vent Open
6 04	1200	13.5	11.5	1/2	1010	55	245	900	2100	91.4	93.7	2090	Vent Open
6 04	1300	14.5	12.5	1/2	1010	55	240	910	2200	94.1	90.6	2190	2 gal fuel
6 04	1400	15.5	13.5	1/2	1010	55	240	900	2150	93.6	89.3	2100	Vent Open
Changed oil to 2190TEP													
6 08	0630	15.5	13.5	3/4	1010	60	280	800	1500	66.5	80.7	0	2 Gal Fuel
6 08	0700	16.0	14.0	3/4	1010	55	240	820	1500	85.7	84.3	1200	
Charge rate 1500 to 2500 psig 24 min 50 sec													Opened Vent
6 08	0800	17.0	15.0	3/4	1010	55	280	900	2100	89.2	87.6	2150	Vent Open
6 08	0900	18.0	16.0	3/4	1010	55	280	880	1600	86.6	85.0	1600	Vent Open
6 08	1000	19.0	17.0	3/4	1010	55	245	880	1600	92.7	92.2	1600	Vent Open
6 08	1100	20.0	18.0	1/2	1010	55	245	900	2100	97.1	89.2	2100	Vnt Opn/2 gal fuel
6 08	1200	21.0	19.0	1/2	1010	55	245	925	2300	99.1	97.6	2280	Vent Open

MAKO DIVERS AIR COMPRESSOR
MODEL 5407 BAD

1989 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
6 11	0630	21.0	19.0	3/4	1000	60	240	820	1500	71.5	90.2	260	Vent Closed
6 11	0700	21.5	19.5	1/2	1000	55	240	820	1500	83.4	87.4	1150	Opened Vent
6 11	0800	22.5	20.5	1/2	1000	60	250	900	2200	93.7	87.1	2200	2 gal fuel
Charge Rate 1500 to 2500 22 min 48 sec added 6 oz oil to diesel /adj Comp oil pressure													
6 11	0900	23.5	21.5	3/4	1010	55	245	940	2500	88.6	88.5	2500	Vent Open
6 11	1000	24.5	22.5	3/4	1010	55	240	860	1900	88.3	94.5	1880	Vent Open
6 11	1100	25.5	23.5	3/4	1010	55	240	850	2100	97.8	93.8	2050	2 gal fuel
6 11	1200	26.5	24.5	3/4	1010	55	240	910	2150	99.3	98.2	2110	Vent Open
6 11	1300	27.5	25.5	3/4	1010	55	245	910	2200	102.	98.7	2150	Vnt Opn/ Air Sample
6 11	1400	28.3	26.5	3/4	1010	55	250	950	2400	103	99.0	2380	Vent Open
6 12	0730		26.5	3/4	1040	55	230	800	1500	80.1	79.4	400	2 gal fuel
6 12	0830		27.5	1/2	1025	55	240	800	1700	88.3	82.1	1650	Opened Vent
6 12	0930		28.5	1/2	1025	55	240	800	2050	91.3	84.2	2000	2.5 gal fuel
Charge Rate 1500 to 2500 23 min 19 sec added 4 oz 2190 TEP To Compressor													

MAKO DIVERS AIR COMPRESSOR
MODEL 5407 BAD

1989 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
6 12	1030		29.5	3/4	1030	55	240	850	1600	94.0	87.7	1590	Vent Open
6 12	1130		30.5	3/4	1030	55	240	860	1700	99.5	96.2	1680	Vent Open
6 12	1230		31.5	3/4	1030	55	245	880	1850	101	98.4	1820	2 gal fuel
6 12	1330		32.5	3/4	1030	55	245	850	2000	100	91.5	1960	Vent Open
6 12	1400		33.0	3/4	1030	55	245	840	1950	99.5	91.4	1900	Vent Open
6 13	0630		33.0	3/4	1010	55	235	810	1500	65.9	79.9	100	Vent Closed
6 13	0730		34.0	3/4	1025	55	240	880	2100	82.9	76.6	2050	Vnt Opn/2 gal fuel
6 13	0830		35.0	1/2	1025	55	240	920	2200	86.6	82.0	2150	Vent Open
6 13	0930		36.0	1/2	1025	55	245	850	1650	88.3	83.1	1600	Vent Open
Charge Rate 1500 to 2500 22 min 50 sec													Opened Vent
6 13	1030		37.0	1/2	1025	55	250	900	2400	96.3	92.4	2380	Stop Test
Changed 1803 filter clean Mk 2C added 2 gallons fuel													
6 13	1200		37.0	1/2	1025	55	250	900	2400	96.3	92.4	2380	2 oz 2190 TEP
6 13	1300		38.0	3/4	1025	55	245	910	2200	98.9	98.1	2150	Vent Open

MAKO DIVERS AIR COMPRESSOR
MODEL 5407 BAD

1989 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
6 13	1400		39.0	3/4	1025	55	250	1000	3000	98.8	96.4	3000	Opened Vent
6 14	0630		39.0	3/4	1040	50	230	800	1500	67.8	79.4	100	2 gal fuel
6 14	0730		40.0	1/2	1025	55	240	860	1900	86.2	85.8	1850	Vent Open
6 14	0830		41.0	1/2	1025	55	240	900	2050	91.3	83.1	2000	Vent Open
6 14	0930		42.0	1/2	1025	55	245	910	2150	94.4	83.3	2100	2 gl fuel/6 oz 2190
6 14	1030		43.0	1/2	1025	55	245	910	2150	96.9	89.2	2100	2.5 gl ful/6 oz2190
6 14	1130		44.0	3/4	1020	55	245	920	2150	98.9	91.9	2100	Vent Open
6 14	1230		45.0	3/4	1020	55	250	920	2200	99.8	94.0	2150	Vent Open
6 15	0730		45.0	3/4	1040	50	230	800	1500	68.3	81.6	0	2 gal fuel
6 15	0830		46.0	1/2	1020	55	240	810	1800	94.3	88.4	1800	Vent Open
6 15	0930		47.0	1/2	1020	55	245	810	2300	95.1	89.6	2250	Vent Open
6 15	1030		48.0	1/2	1020	55	240	800	1600	94.0	87.4	1580	2 gal fuel
Charge Rate 1500 to 2500 psig 22 min 52 sec													

MAKO DIVERS AIR COMPRESSOR
MODEL 5407 BAD

1989 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	OIL LEV	OIL PR	STAGE PRESSURES				TEMPS		FLASK PRESS	REMARKS
						1	2	3	4	DSCH	AMBI		
6 15	1130		49.0	1/2	1020	55	240	900	2100	95.5	90.0	2050	Vent Open
6 15	1230		50.0	1/2	1020	55	245	900	2000	95.1	87.5	1950	Secure Test
						Fuel	top	up	2.5	gal			Air Sample

Memorandum 4 June 1990

To: Dave Sullivan, NEDU
From: G. Deason, Code 5130 1 HOUR

Subject: Analysis of the Mako 1 hr test sample, test# 90-15.

1. In accordance with your request, on 4 June 1990 the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0%
Nitrogen	78.1%
Argon	0.9%
Carbon Dioxide	<25 PPM
Carbon Monoxide	<0.5 PPM
Total Hydrocarbons*	2.1 PPM
Total Halogens**	<0.5 PPM
Methane	2.1 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
C4+	<0.1 PPM

*Expressed as methane equivalents.
**Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason
Chemist

Memorandum 12 June 1990

To: Dave Sullivan, NEDU
From: G. Deason, Code 5130

Subject: Analysis of the air sample from the Mako compressor after 25 hours, test# 90-15.

1. In accordance with your request, on 12 June 1990 the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0%
Nitrogen	78.1%
Argon	0.9%
Carbon Dioxide	368 PPM
Carbon Monoxide	<0.5 PPM
Total Hydrocarbons*	3.3 PPM
Total Halogens**	<0.5 PPM
Methane	3.3 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
Methylchloroform	<0.1 PPM
C4+	<0.1 PPM

*Expressed as methane equivalents.
**Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason
Chemist

Memorandum 18 June 1990

From: Glen Deason, Code 5130
To: Dave Sullivan, NEDU

1. In accordance with your request, on 18 June 1990 the air sample from the Mako HP air compressor, test no. 90-15, was analyzed and found to contain:

Compents	Results
Oxygen	21%
Nitrogen	78.1%
Argon	0.9%
Carbon Dioxide	338 PPM
Carbon Monoxide	<0.5 PPM
Total Hydrocarbons*	3.7 PPM
Total Halogens**	<0.5 PPM
Methane	3.7 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Benzene	<0.1 PPM
Toluene	<0.1 PPM
C4+	<0.1 PPM

* Expressed as methane equivalents.
** Expressed as methyl chloride equivalents.

2. The sample showed no appreciable contamination. All components were within the acceptable range (as per the U.S. Navy Diving Manual).

Glen Deason
Chemist

		5406E	5407
First stage suction connection.....NPT		1	1
Compressor (bare) height.....in		27	27
	mm	685	685
Compressor width.....in		22	22
	mm	559	559
Compressor length.....in		19	19
	mm	483	483

2.7 WEIGHT

Complete (approximately).....lbs		661	680
	kgs	300	308

2.8 SPEEDS

Compressor speed.....rpm		1800	1800
Mean piston speed.....ft/s		11	11
	M/s	3.35	3.35
Max acceptable vibration level in any direction on the valves.....mm/s		40	40

2.9 TEMPERATURES

Ambient and air inlet temperature.....min	F	14	14
	C	-10	-10
max	F	113	113
	C	45	45

NOTE: It is extremely difficult to accurately record air temperatures by the surface metal temperature, due to air flow from the fan cooling down the reading. However, as a general guide, no metal surface temperature should exceed 160 C (338 F).

2.10 LUBRICANTS

Recommended oil - mineral.....Mako Compressor Oil			
Recommended oil - synthetic.....Mako Super Synthetic Oil			
Sump capacity.....pts		2.5	2.5
	ltrs	1.4	1.4
Recommended grease for assembly....Silicone			

SECTION 2 SPECIFICATIONS

2.1 UNIT DESIGNATION

A belt driven, high pressure, air cooled compressor 5406E 5407

2.2 TECHNICAL DATA

Type.....Four stage, four cylinder - V configuration

Cooling.....Fan activated air

Direction of rotation viewed from drive end.....Anti-clockwise

Type of valves.....Single & combined multi-ported

Intake silencer/air filter.....Dry

2.3 STAGE PRESSURES

	DELIVERY psig	1ST STAGE psig	2ND STAGE psig	3RD STAGE psig
5406E	1000	36/40	155/180	550/650
	2000	37/41	170/195	700/800
	3000	38/42	190/215	820/920
	4000	39/43	205/230	910/1010
	5000	43/47	215/240	1000/1110
5407	1000	56/62	240/272	742/855
	2000	57/63	246/276	857/975
	3000	58/64	253/284	962/1085
	4000	59/65	259/290	1060/1185
	5000	60/66	265/295	1150/1270

OIL PRESSURE - 1000 PSIG (68.9 bar) 5406E 5407

MAXIMUM INLET PRESSURE - 6 psig, - 0.5 psig

SAFETY VALVE SET PRESSURES

1st Stage.....psig	50	85
2nd stage.....psig	300	385
3rd stage.....psig	1400	1400

2.4 GENERAL

		5406E	5407
Charging rate.....	ft3/m	12.9	18.7
	M3/hr	22	31.8
First stage piston displacement....	ft3/m	17.5	23.3
	M3/hr	29.8	39.6
Compressor power.....@5000 PSI	hp	9.79	14.9
	Kw	7.30	11.1
@2100 PSI	hp	8.65	12.3
	Kw	6.45	9.2
Volume free air delivered.....@5000 PSI	ft3/m	10.3	15.0
	M3/hr	17.5	25.5
@2100 PSI	ft3/m	11	15.8
	M3/hr	18.7	26.8
Noise level at 3 meters.....	dB(A)	80	82
Cooling air flow rate (approx).....	ft3/m	2942.	4120
	M3/hr	5000	7000

2.5 INCLINATION

Permissible inclination of machine:

Front to rear side.....	degree	10	10
Left or right.....	degrees	20	20

2.6 DIMENSIONS

First stage cylinder bore.....	in	3.15	3.62
	mm	80	92
Second stage cylinder bore.....	in	1.97	1.97
	mm	50	50
Third stage cylinder bore.....	in	0.87	0.87
	mm	22	22
Fourth stage cylinder bore.....	in	0.43	0.43
	mm	11	11
Stroke.....	in	2.20	2.20
	mm	56	56
Final delivery O/D pipe connection.....	in	0.312	0.312
	mm	8	8